

**IN THE SPECIFICATION:**

Please amend the Title of the Invention from "SINGLE COIL OF COIL UNIT FOR LINEAR MOTOR, METHOD AND DEVICE FOR WINDING AND FORMING THE SAME, AND METHOD FOR FORMING AND FABRICATING COIL UNIT" to --A METHOD FOR WINDING A SINGLE COIL OF A COIL UNIT FOR A LINEAR MOTOR--.

Please amend the originally filed Specification as follows:

**[0046]** ~~FIG. 2 is a diagram containing~~ FIGs. 2A-2C illustrate a front view, a plan view, and a longitudinal sectional view, respectively, ~~showing the configuration of a~~ winding former in the above-mentioned embodiment;

**[0047]** ~~FIG. 3 is a diagram containing~~ FIGs. 3A-3D are perspective views showing the steps of winding a wire in the above-mentioned embodiment;

**[0049]** ~~FIG. 5 is a diagram containing~~ FIGs. 5A-5C illustrate a front view, a plan view, and a longitudinal sectional view, respectively, ~~showing the exploded configuration of a first forming device in the above-mentioned embodiment;~~

**[0051]** ~~FIG. 7 is a diagram containing~~ FIGs. 7A-7B illustrate exploded front and side views, respectively, of the first forming device shown in ~~showing the state of~~ FIG. 6 combined with an additional forming tool;

**[0052]** ~~FIG. 8 is a diagram containing~~ FIGs. 8A-8B illustrate longitudinal sectional views of a coil unit;

**[0054]** ~~FIG. 10 is a diagram containing~~ FIGs. 10A-10C illustrate perspective views sequentially showing the conventionally known steps of fabricating a coil unit for a linear motor ~~disclosed in Japanese Patent Application Laid Open No. 2001-67955.~~

**[0057]** A single coil 12 to be wound by this winding device basically has the same fundamental shape as that of the single coil 2 according to Japanese Patent Application Laid Open No. 2001-67955 which has been described in conjunction with FIGs. 10A-10C ~~FIG. 10~~. Thus, in the following description, the parts having identical or similar functions to those of the single coil 2 will be designated by 10-odd numerals having the same last one figures. That is, the entire single coil 12 is shaped like a generally rectangular ring. Opposed two sides of this rectangular function as effective conductors 14, which contribute to producing a thrust in the moving body of a linear motor. The other two opposed sides function as connecting conductors 16 for connecting the effective conductors 14.

**[0065]** ~~FIG. 2 shows~~ FIGs. 2A-2C illustrate a specific structure of the winding former 40. The winding former 40 comprises a first piece 42 and a second piece 44.

**[0068]** The first winding parts 42a of the first piece 42 are formed as sloped such that is departs from the second piece toward the ends of the first winding parts 42a. This configuration aims to maintain favorable accommodation between the connecting conductors 16 of a plurality of single coils 12 when the single coils 12 are arranged to form a coil unit for a linear motor (to be described later in conjunction with FIGs. 8A-8B ~~FIG. 8~~).

**[0078]** Referring to FIGS. 1 and 3A-3D ~~3~~, the conductive wire W that is fed out in the direction of the Z-axis through the coil bobbin 24, the guide roller 26, and the guide arm 28 is bent around the lock P1 of the winding former 40, into an initial state where a first effective conductor 14f is formed as shown in ~~(a) of~~ FIG. 3A ~~3~~. To form this initial

state, the conductive wire W itself may be bent directly. The rotation of the winding former 40 about the X-axis may be combined.

**[0079]** In this state, the winding former 40 is rotated by 180 degrees about the Y-axis by the second rotating mechanism 52. This rotation first causes torsion at the lock P1, whereby the conductive wire W is firmly locked to the lock P1. With this lock P1 as a start point (or origin), the winding former 40 is rotated to the lock P2, or equivalently the end point, along the conductive wire W that is fed newly. This stretches a first connecting conductor 16f as shown in ~~(b)~~ of FIG. 3B 3. This "stretch" is effected so that the winding former 40 "aligns to" the newly-fed, stress-free conductive wire W. Therefore, little side force (torsional stress) occurs in the plane that includes the Z-axis and the connecting conductor 16. That is, despite an irregular-shape coil, the torsion occurring at the lock P1 hardly propagates to the next lock P2.

**[0080]** After the state ~~(b)~~ in FIG. 3B is formed, the winding former 40 rotates by 180 degrees about the X-axis. This rotation causes torsion at the lock P2 this time, whereby the conductive wire W is firmly locked to the lock P2. With this lock P2 as the start point (or origin), the winding former 40 is rotated along the conductive wire W up to the lock P3, or equivalently the new end point. This stretches a next effective conductor 14s as shown in ~~(c)~~ of FIG. 3C 3. This "stretch" is also effected so that the winding former 40 "aligns to" the newly-fed, stress-free conductive wire W. Therefore, little side force (torsional stress) occurs in the plane that includes the Z-axis and the effective conductors 14. That is, the torsion occurring at the lock P2 hardly propagates to the next lock P3, either.

**[0081]** Then, the winding former 40 is rotated by 180 degrees about the X-axis again, the stretch from the lock P3 to P4 is performed in nearly the same manner as with the stretch from the lock P1 to P2 in FIG. 3A ~~3(a)~~ described above. As a result, a next connecting conductor 16s is stretched into the state in FIG. 3D ~~(d)~~, completing a single round of winding.

**[0082]** Subsequently, the operations ~~(a) through (d)~~ shown in FIGs. 3A-3D are repeated until the counters 70 and 72 indicate predetermined numbers of wind (numbers of turns) to end the winding operations.

**[0092]** Now, return to FIGs. 10A-10C ~~FIG. 10~~ to reexamine the method of overlapping the coil sheets 3 (3a). In this method, for example, the flanges 8 for forming the connecting conductors 6 could not but have a thickness D greater than or equal to the thickness Wc of the effective conductors 4. In contrast, the single coil 12 fabricated by the method or device according to the embodiment may take a variety of shapes by selecting the dimensions of the first and second winding parts 42a and 44 (see D1, D2 in FIGs. 2A-2C ~~FIG. 2~~) and the number of turns. The lengths L1 and L2 of the effecting conductor portions 14 and the connecting conductors 16 may also be selected arbitrarily, and can be set freely without precluding the winding.

**[0099]** The single coil 12 formed thus is cooled and then released from the forming tool 70 and the winding former 40. In this manner, a plurality of single coils 12 are prepared. The single coils 12 prepared are loaded into a forming device 80 for a unit as shown in FIGs. 5A-5C ~~FIG. 5~~, and fastened temporarily. The forming device 80 is composed of a pair of main bodies 82 and 84 each having grooves 81 for accommodating the single coils 12, and a pair of covers for enclosing both sides

thereof. Here, the main bodies 82 and 84 hold the single coils 12 with no gap therebetween. The connecting conductors 16 are distributed to right and left alternately with respect to the traveling direction.

**[0102]** In this method, the single coils 12 wound around the winding formers 40 are released as it is from the winding formers 40 without being formed by the forming tool 70 described above. The single coils 12 released are loaded into the grooves 81 of the forming device 80 shown in FIGs. 5A-5C ~~FIG. 5~~, and fastened temporarily.

**[0103]** Thereafter, the single coils 12 are connected according to the specifications of the coil unit 62, and loaded into such a second forming device 90 as shown in FIGS. 6 and 7A-7B ~~7~~ for temporary fastening.

**[0108]** Referring to FIGS. 8 8A and 8B through 9 and returning to FIGs. 10A-10C ~~FIG. 10~~, a plurality of single coils 12 are used as single coils 12U, 12V, and 12W for U, V, and W phases, respectively. These three-phase single coils 12 are assembled in the following manner. Initially, two single coil groups are prepared. In each group, single coils 12 are arranged so that their effective conductors 14 adjoin one another with no gap between the outer sides thereof. The connecting conductors 16 are bent in opposite directions across the traveling direction A (in FIG. 9, the single coil group arranged above in an inversed U-shape and the single coil group arranged below in a U-shape). Then, the single coils 12 in the respective groups are opposed to each other so that the opening of each effective conductor 14 of one group accommodates ends of two effective conductors 14 of the other group. The result is that the effective conductors 14 are arranged at a regular pitch. Here, as shown in FIG. 9, the single coils in one group are arranged in the order of U, V, W, U, V, W, . . . , and the single coils in the other

group are also arranged in the order of U, V, W, U, V, W, . . . . Then, both the single coil groups are adjusted in phase so that ends of V- and W-phase effective conductors 14 of one group lie between the effective conductors 14 of the U-phase single coils 12 of the other group.

**[0109]** As a result, the cross sections of the U-, V-, and W-phase effective conductors 14 come in succession along the traveling direction. This arrangement is achieved by the use of the single coils 12 that have the connecting conductors 16 bent at approximately 90 degrees with respect to the effective conductors 14. Merely two phases of coils will appear as seen in a cross section perpendicular to the traveling direction (see FIGs. 8A-8B ~~FIG. 8~~). This arrangement is extremely advantageous since no more than a single type of single coils 12 is needed.

**[0110]** As mentioned previously, in this embodiment, the first winding parts 42a of the first piece 42 of the winding former 40 are sloped away from the second pieces 44 toward the ends of the first winding parts 42a. In the absence of these slopes, interference with adjoining single coils 12 would be inevitable unless the connecting conductors 16 had a considerably great right-to-left width W1 with respect to the traveling direction as shown in ~~(a) of~~ FIG. 8A 8. Then, the presence of the slopes allows compact accommodation with no wasted regions R as shown in ~~(b) of~~ FIG. 8B 8. As a result, the width W1 can be reduced down to the width W2. This reduction contributes to a reduced right-to-left width with respect to the traveling direction of the linear motor LM. At a given width, the casing can be made with a greater thickness for stabler moving. Depending on the design, greater thrust can be produced.

**[0114]** This also makes the coil resistances 1.5 times, however. At a given driver supply voltage, the maximum possible current decreases to  $1/1.5$  times with no change in  $I_0 L_1$ . The result is that while the thrust becomes 1.5 times, the width  $W_2$  of each connecting conductor 14 (see FIGs. 8A-8B ~~FIG. 8~~) also becomes 1.5 times for poor accommodation. Now, if the cross-sectional areas of the windings can be increased 1.5 times for nearly the same space factor,  $I_0$  can be rendered 1.5 times at a given  $L_1$ . In this case, the thrust becomes the square of 1.5, or 2.25 times.